Fossil features of mulga *Acacia aneura* landscapes: possible imprinting by extinct Pleistocene fauna

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ABSTRACT

Preliminary observations of suspected fossil soil features found across a wide range of mulga *Acacia aneura* landscapes in semi-arid New South Wales and Queensland are described. Because of the radial symmetry and size of these features an hypothesis of early Holocene, possibly even late Pleistocene, construction by now-extinct ground-nesting or burrowing fauna is proposed.

Key words: Mulga, Burrowing Bettong, Surface-soil features, Bioturbation, Geochronology.

INTRODUCTION

The occurrence, and disposition, of two relict surface-soil features in semi-arid mulga *Acacia aneura* communities were reported earlier by Noble (1993). Some features — circular mounds, usually around 10 m in diameter — often exhibited a distinct central depression. A Terrestrial Megapode Hypothesis was subsequently proposed to explain their construction based on nest building by the now-endangered Malleefowl *Leipoa ocellata*. The other features were much larger, many around 30 m in diameter, all characterized by a sub-circular morphology ranging from a lunate shape to one approximating a giant horse-shoe (Noble 1997). A common characteristic of the latter features was the presence of a distinctive perimeter mound surrounding a central calcrete lens within a large depression. Because the now regionally-extinct Burrowing Bettong *Bettongia lesueur* (Short 1998) was known to construct large warrens in other arid regions (e.g., Finlayson 1958; Myers and Parker 1965), a Fossorial Macropod Hypothesis was postulated for their construction (Noble 1993).

This short communication provides additional details of two larger features observed throughout north-west New South Wales and south-west Queensland, and canvasses their age and evidence for it.

FIELD OBSERVATIONS

Details of the location, form, dimensions, geometry and local vegetation of representative features are summarized in Table 1. More detailed descriptions, together with a preliminary analysis of the possible causes of their formation, are outlined below.

(a) Circular features

Large, circular mounds with diameters commonly around 20 m have been observed in "hard" mulga landscapes (massive red earth soils) at six sites in the Bulloo-Paroo-middle Darling drainage basins. These features are usually remarkably well preserved, exhibiting minimal evidence of erosion or weathering with upper surfaces noticeably higher (30–50 cm) than the surrounding land surface. Superficial excavations of some mounds have often shown a dense, central core much ramified with termite (*Drepanotermes* and *Amitermes* spp.) galleries. It is not uncommon to find mature mulga trees of indeterminate age growing in the central depression (Fig. 1a).

(b) Sub-circular features

Attention to other possible vestiges of bioturbation was also aroused during seasonal large-scale aerial photography. These features were exposed during the extended drought period of the early 1990s in the West Darling region of New South Wales when there was minimal herbage cover obscuring soil-surface patterning. Aerial surveys undertaken during this period on "Lake Mere" Station, *c.* 30 km north-west of Louth, indicated that residual warrens of the Burrowing Bettong *Bettongia lesueur*, mostly re-worked by Rabbits *Oryctolagus cuniculus*, were closely integrated with a larger-scale and more subtle soil patterning.

This patterning was visible mainly through slight changes in surface-soil colour apparent in colour photographs taken during the survey (Fig. 2). It comprised larger (*c.* 100 m diameter), sub-circular patterns surrounding the smaller, modern warrens, and appeared to be margined within ancient, calcrete-dominant perimeter mounds. The higher concentration of light-coloured calcrete, possibly inverted by past fossorial warren-building activity, contrasted with the deeper red of the ubiquitous red earths. These larger features often contained significant stands of mature trees, especially poplar box *Eucalyptus populnea*, again of indeterminate age (Fig. 3a).

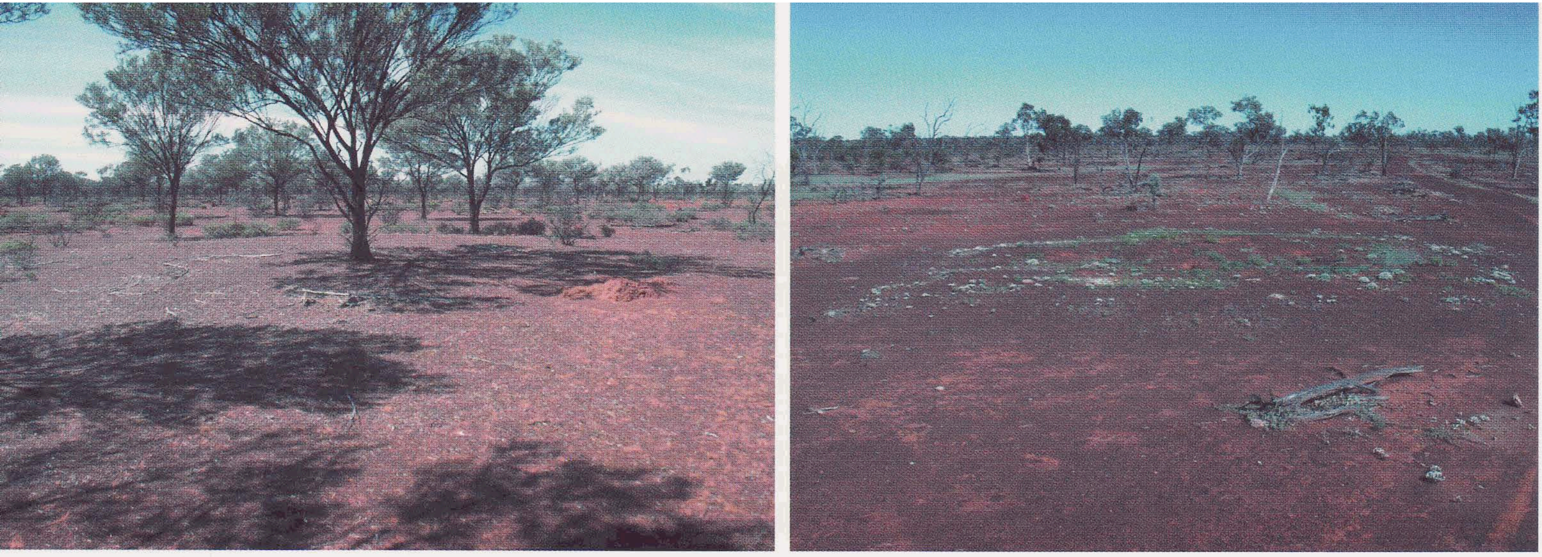


Figure 1. Large circular mounds in semi-arid mulga *Acacia aneura*. (a *left*) "Wareo" Station, Cooladdie, Queensland where a mature mulga and termite nest are visible in the central depression. No shrub understorey is present. (b *right*) "Moama" Station, Eulo, Queensland. The perimeter mound has a distinctive cover of ephemeral herbs.

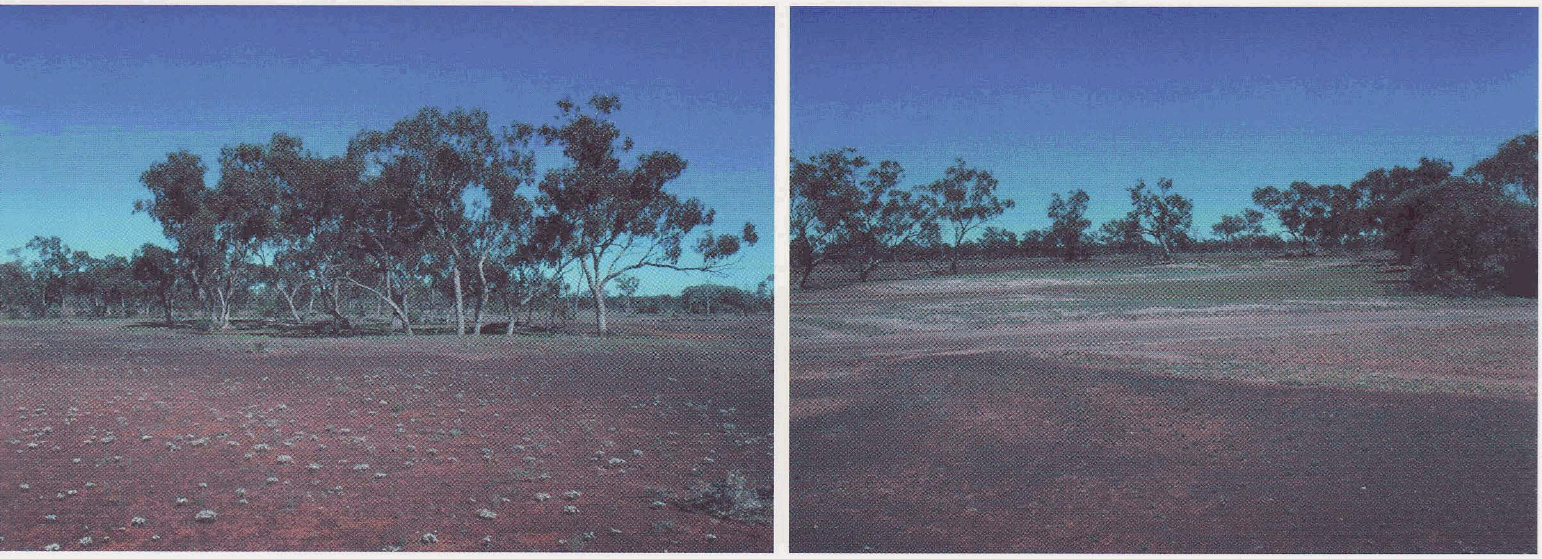


Figure 3. Ground perspectives of large, sub-circular features on "Moama" Station, Eulo, Queensland (numbers 6 and 7 in Table 1) in mid-slope sites adjacent to ephemeral drainage lines. A stand of large Poplar Box *Eucalyptus populnea* trees is shown in a *(left)*.

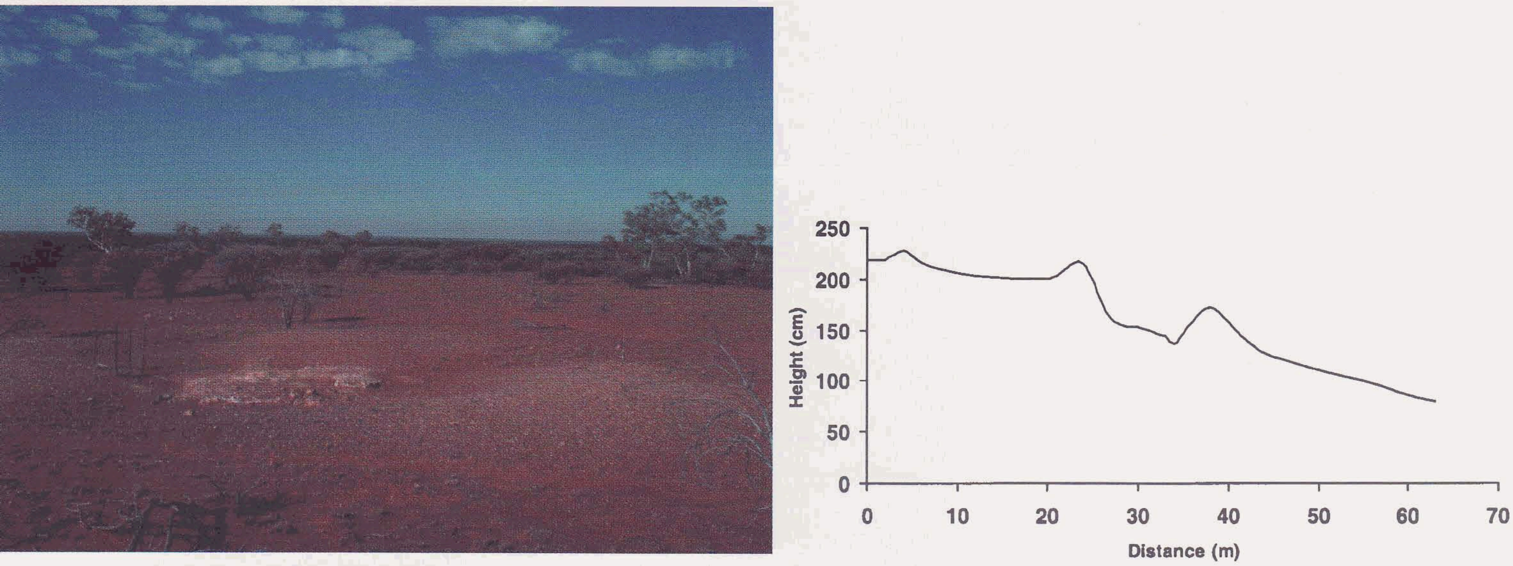


Figure 4. (a *left*) Typical sub-circular warren constructed by Burrowing Bettongs *Bettongia lesueur* during Recent geological time showing a calcrete lens clearly exposed in the centre. The lighter-toned deposits of calcrete on the semi-circular perimeter mound indicate the direction of drive of three major tunnels excavated by Burrowing Bettongs. "Glenora" Station, west of Bourke, New South Wales. (b *right*) Topographic profile of a typical Burrowing Bettong warren on "Glenora" showing the characteristic change in slope above and below the warren.

Table 1. Dimensions, form, location and habitat details of large relict features observed in mulga *Acacia aneura* communities in semi-arid New South Wales and Queensland.

Number	Site	Waypoints (UTMs)	Geometry	Dimensions (m)	Vegetation
(1)	"Gambolalley" Bourke, NSW	332 159 6636 965	Circular	14 × 20	Open grassland, principally *Stipa* spp.
(2)	"Moama" Eulo, Queensland	287 122 6948 631	"	18 × 18	Light cover of mixed forbs
(3)	"Wareo" Cooladdi, Queensland	276 589 6928 422 (homestead)	"	20 × 20	Minimal herb cover. One mature mulga established in depression
(4)	"Lake Mere" Bourke, New South Wales (several sites located in Channel paddock)	(e.g., site No. 2386) 297 728 664 6798	Sub-circular	100 × 50	*Sclerolaena diacantha* dominant herb. Abundant *Stipa* spp. after good rain
(5)	"Bundoona" Eulo, Queensland	281 189 6906 215	"	44 × 48	*Enneapogon* spp., *Chenopodium cristatum* and *Sclerolaena paradoxa* dominant ground species
(6)	"Moama" Eulo, Queensland	287 128 6948 496	"	39 × 46	Several large *Eucalyptus populnea* trees in central depression. *Chenopodium cristatum* dominant herb
(7)	"	287 541 6948 475	"	94 × 48	*Atriplex* spp. on grey soil and *Enneapogon* spp. on calcrete perimeter mound

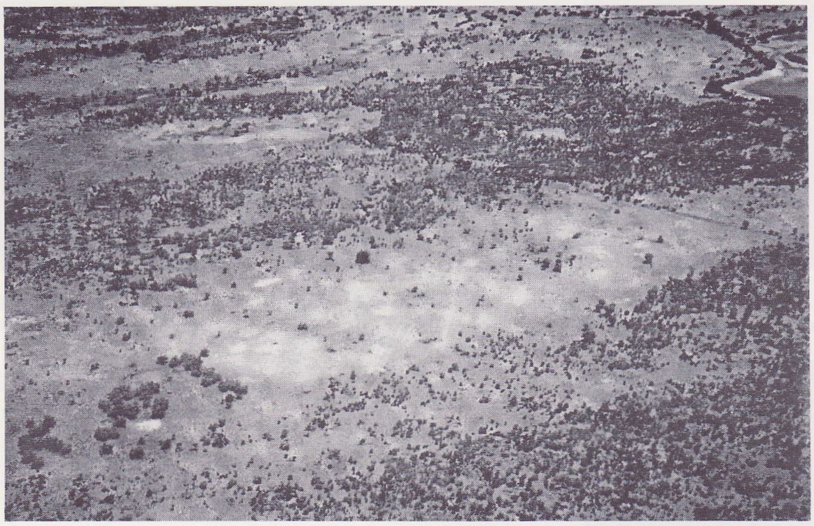
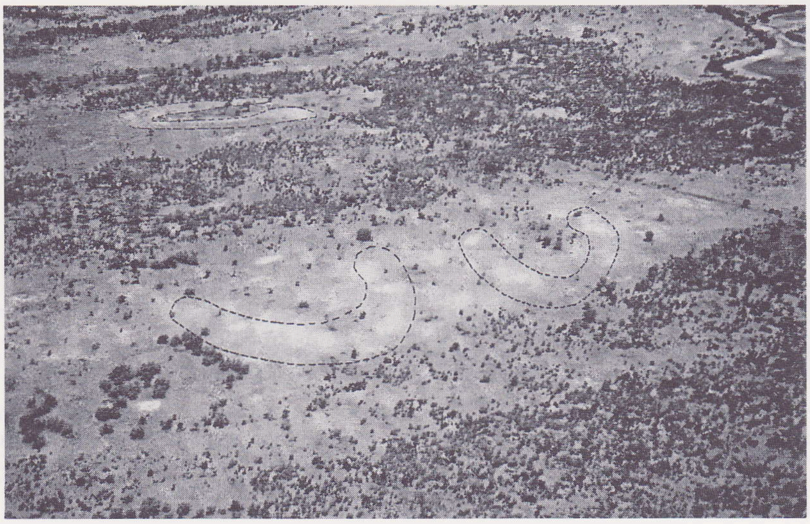


Figure 2. Oblique aerial perspective of surface-soil patterning in a calcareous landscape. Channel paddock, "Lake Mere" Station, Bourke, New South Wales. (a *left*) More recent patterns of warren construction by Burrowing Bettongs *Bettongia lesueur* and later Rabbits *Oryctolagus cuniculus*, overlie a more diffuse, larger-scale patterning highlighted in (b *below*).



DISCUSSION

Detailed examination of large-scale, aerial colour photography has established the presence of distinctive, though often subtle, surface-soil patterning detectable in semi-arid landscapes of the Bulloo-Paroo-middle Darling drainage basins. That these are residues of structures created by now-extinct mound- or warren-building vertebrates in the recent past is postulated here. The structures served to maintain a high degree of mesoscale (50 m up to 1 km) surface heterogeneity that, in turn, structured both plant and animal communities (Holling 1992). This landscape heterogeneity has undoubtedly influenced a number of fundamental landscape processes and vegetation dynamics (Ludwig *et al.* 1997). Clones of rosewood *Alectryon oleifolius* trees were often found growing in sub-circular stands that were closely associated with calcareous soils in the region (Ludwig and Tongway 1995). Whether these stands were established on ancient perimeter mounds, or the trees themselves have encouraged the precipitation of either pedogenic (English 1998) or biogenic (Goudie 1996) calcrete over time, is unknown.

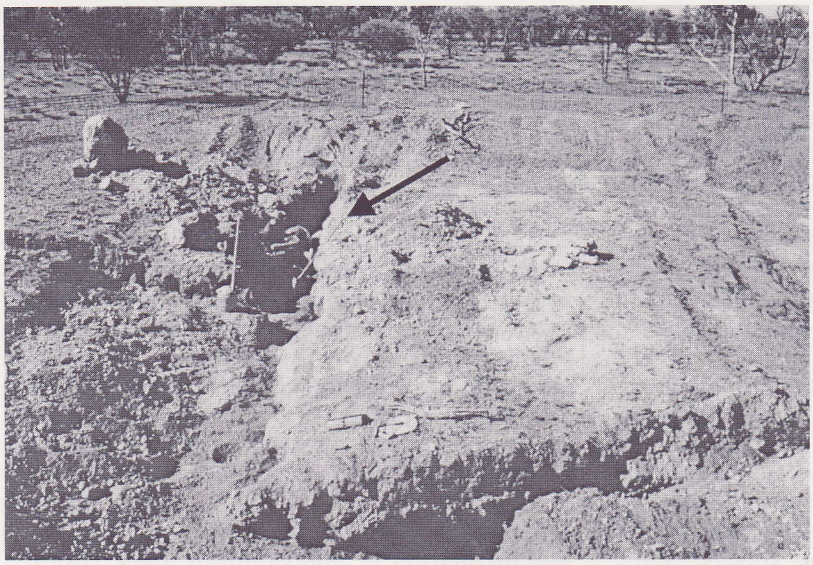
The actual mechanism responsible for the construction of these radially symmetrical fossil features is obviously still a matter of some conjecture. Both features are much larger versions of those constructed by animals such as the Malleefowl *Leipoa ocellata* and Burrowing Bettong *Bettongia lesueur* that were active in these regions up until the end of the 1800s. It therefore seems logical to look for larger analogues of these "landscape engineers" (Noble *et al.* 1999). If future dating establishes that some of the circular features were constructed prior to the Holocene (i.e., >10 000 years BP), the question then arises as to whether they might have been built by now-extinct mound-building birds. Two such megapodes existing then were *Progura gallinacea* and *P. naracoortensis* (Fig. 4a), both weighing around 7 kg (van Tets 1974). These species are regarded as Pleistocene relatives of the modern Malleefowl with *P. naracoortensis* recorded from one late Pleistocene deposit in Victoria Fossil Cave, South Australia (Baird 1991). Nonetheless, all known fossils of *P. naracoortensis* exceed 200 000 years in age (van Tets 1974; J. Magee, pers. comm.).

The galleries evident within these circular mounds were probably constructed by the ubiquitous Harvester Termite *Drepanotermes perniger*, suggesting that moderate quantities of organic material were present initially, as in active megapode nests, so as to attract large numbers of these decomposers. Carton excreted by termites during gallery construction has also made these mounds, like circular termite pavements (Noble *et al.* 1989), particularly resistant to weathering. Whether such deposits can be accurately dated using modern techniques remains to be seen. But if so, they may well date the time of construction of the features.

Megapodes such as the Malleefowl *Leipoa ocellata* have generally depended on the regular supply of substantial quantities of litter in order to generate sufficient heat from decomposition for optimal egg incubation (Frith 1962). Recent observations of active Malleefowl mounds in arid northwestern South Australia suggest that abundant quantities of leaf litter from woody species such as mallee (*Eucalyptus* spp.) are not an essential prerequisite for mound building and successful egg incubation (J. Benshemesh, pers. comm.). Higher ambient temperatures in Central Australia during early spring may offset the need for sustained, decompositon-induced nest temperatures. Nonetheless, significant changes in vegetation structure and composition since the large circular mounds reported in this paper were last active, cannot be discounted entirely.

The semi-circular form of the larger features is also similar to the shape of Recent sub-circular warrens constructed by the Burrowing Bettong (Fig. 4a, b), suggesting that an earlier fossorial analogue of this species may have been responsible for their construction. However, detailed examination of their morphology and landscape relationships, remain to be undertaken. Burrowing Bettong warrens in the West Darling region clearly act as major obstruction elements trapping large quantities of runoff-transported topsoil and organic matter above, and within, the warren (Fig. 4b). Preliminary excavations of now-disused warrens in the West Darling region (Fig. 5) indicated that individual tunnels excavated by Burrowing Bettongs generally followed zones of weakness in the pedogenic calcrete lens. These tunnels eventually terminated when they reached the interstitial zone separating the lens from the underlying base of sheetflow calcrete (English 1998). Subsequent chemical analysis of vertically stratified soil samples taken at different points along an exposed tunnel provided an outline of the disposition of soil nutrients, particularly soil organic carbon (Colwell 1969), in both external and internal microsites (Fig. 6).

The crescentic patterns of macro-features, together with the inverted calcrete evident in what appear to be semi-circular perimeter mounds, are strongly indicative of prior fossorial activity. Whether the Giant Rat



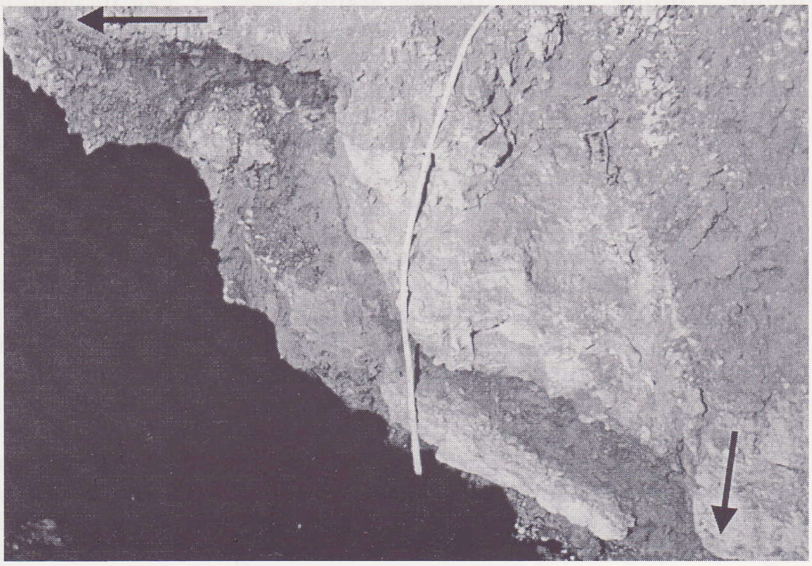


Figure 5. (a *above*) A Burrowing Bettong warren being excavated on "Glenora" Station. (b *right*) A tunnel exposed following excavation of the trench arrowed in (a) and now completely filled with soil and organic matter. The left hand arrow in (b) indicates the entrance while the other shows the point where the tunnel enters a chamber located between the lens and underlying sheetflow calcrete.

Kangaroo *Propleopus oscillans* for example, an omnivorous marsupial weighing around 40 kg (Archer and Flannery 1985; Sanson 1991), was fossorial or not, is unknown. One reconstruction of this species (Rich *et al.* 1985) portrays a powerful musculature of the forearms and shoulders although the long and slender humerus is more indicative of a non-burrowing species (T. Flannery, pers. comm.). Other elements of the Pleistocene megafauna, including several wombat species (e.g., *Ramsayia*, *Phascolonus*, *Phascolomys* and *Vombatus* spp.) (Flannery 1994), may have been fossorial, as were *Lashiorhinus barnadi* and *L. kreftii*, species widespread in prehistory. However, their warren systems, like contemporary ones, were probably amorphous with randomly located entrances.

An alternative hypothesis might be that both features were simply larger nests built by modern species of malleefowl and rat kangaroos during favourable pluvial periods of the early Holocene when climatic conditions, and/or the absence of European disturbance, possibly enabled higher carrying capacities and more stable populations. Furthermore, a geomorphologically-based hypothesis cannot be discounted for the larger features which may simply represent subdued remnants of elements inherited from earlier fluvial landscapes following inversion of relief, as mooted elsewhere (Noble 1993). It is unlikely however, that the semi-circular macro-features shown in Figure 2 represent fossil oxbows of past watercourses since their orientation is generally opposite to that normally found in modern oxbows, i.e., where the two ends adjoin the active, or deepest, stream channel. Furthermore, calcrete deposition is rarely associated with such fluvial features.

The highly speculative nature of this short communication needs to be emphasized. While there is clearly a considerable body of ecological history imprinted in these landscapes,

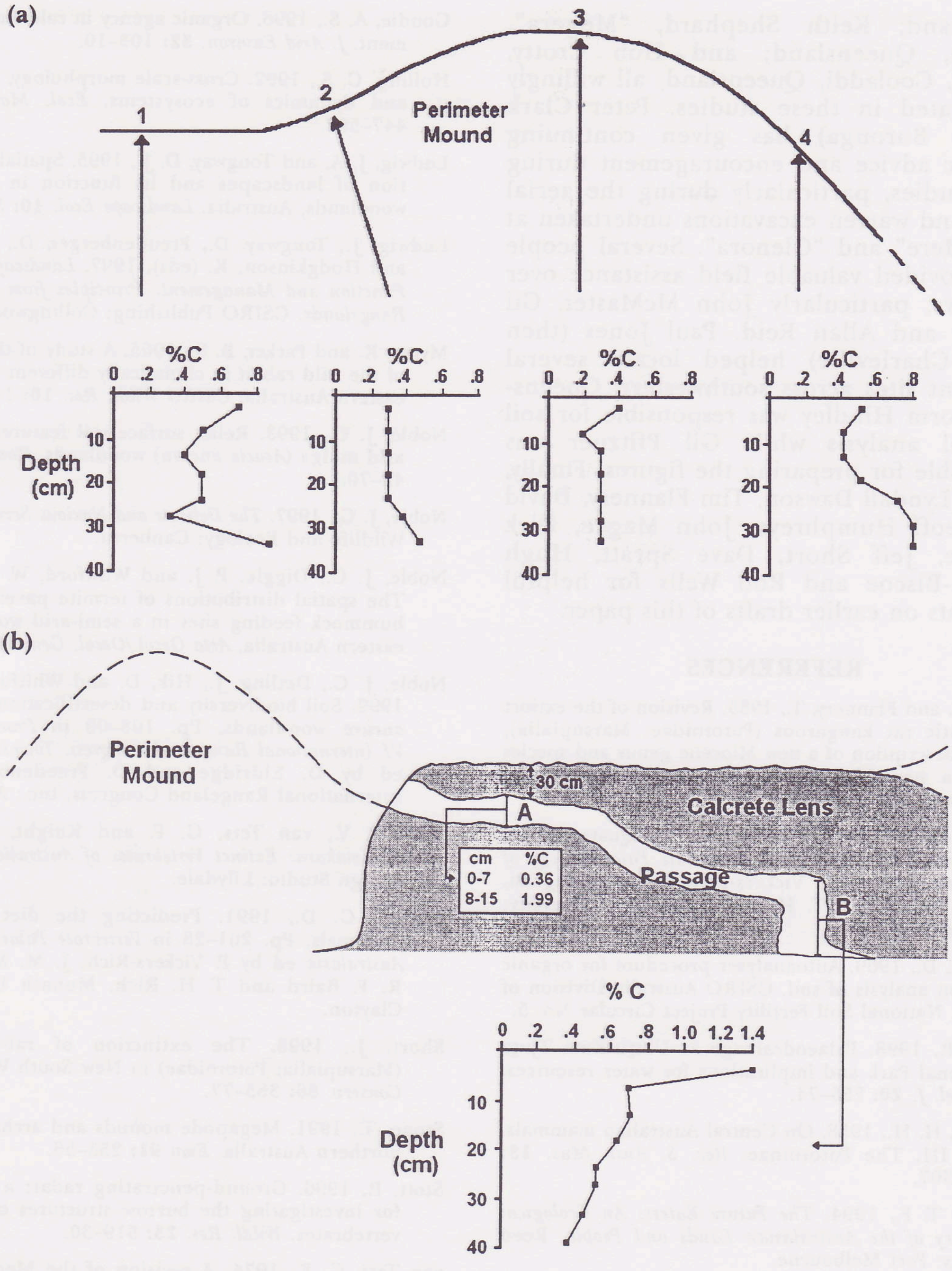


Figure 6. Diagrams (not to scale) illustrating the distribution of soil organic carbon (C) within a disused Burrowing Bettong warren on "Glenora": (a) at four microsites (1, 2, 3 and 4) within the external perimeter mound; and (b) at two points (A and B) within the tunnel shown in Figure 5b.

the challenge remains to apply appropriate, and reliable, dating and archaeological techniques to establish a sound geochronology. These may include a combination of optically stimulated thermoluminescence and radiocarbon dating, advanced remote sensing, and ground-penetrating radar (Stott 1996), together with more traditional and established techniques as proposed for megapode mounds elsewhere (Stone 1991), to help unravel much of this ecological record.

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